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The past decade has been marked by spectacular events in science and technology. The launching of Sputnik I in October 1957 was followed by public hysteria in the United States over the low estate of our education in science punctuated by repeated failures of our technology represented by our Vanguards. Less than a decade later we find space cluttered with assorted vehicles, whole and fragmented, going nowhere very rapidly. In the later years we have smashed new and functional television cameras on the moon, sent an electronic observatory near the planet Venus, and sent a computerized camera whizzing past Mars. While this was going on, earth-bound investigators have discovered negative matter, established values of parity in physics (but not in agriculture), and listened to radio messages from billions of light years away. The genetic code has been broken and we are now ready to produce custom built descendants. However, it appears that the usual variety is being mass produced in staggering numbers by unskilled laborers just for the fun of it. Routine investigations have continued and we are all but buried in the ever increasing flood of paper. Attempts to summarize the situation result in incomprehensible, and perhaps, misleading, statements such as "The body of knowledge in any field of science doubles every ten years." "Ninety percent of all the scientists who have ever lived are here right now." Those in academic institutions are reproducing themselves every two or three years but not fast enough to staff the insatiable appetite of the "great society" for scientific manpower.

Roy

At the beginning of this decade in 1955 we observed the beginnings of curriculum reform in mathematics and the sciences. It has been said that "the greatest scientific event in this country since World War II was the discovery of the high schools." The proliferation of projects from SMSG through PSSC and all the rest has been a major phenomenon of the decade. The materials produced for science courses in the secondary schools are, in fact, concept centered and can succeed only when the student becomes fascinated with learning through discovery. These materials attempt to present science as a way of life, the art of learning the unknown, as unfinished business, and not as a body of knowledge to be memorized. Scientists are trying to reveal themselves as ordinary men and women fascinated with learning rath-

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er than with knowing. However, these materials cannot be effectively presented by unqualified teachers, overworked in overcrowded and underequipped schools. Few secondary teachers have the background, time, or facilities to discover for themselves the fascination of learning. If they did, the hue and cry from confounded and frustrated parents would likely force them back to the security of accepted and acceptable facts. Parents believe that the schools should transmit the tiny world of knowledge and not try to get the students to discover the universe of ignorance which surrounds it. However, the students are not so easily confounded and the message is getting through to them in increasing numbers. These are the students who are bored by much that happens to them in the first year of college.

Scientists working on courses for the high schools soon discovered the junior high schools and the folly known as general science. Beyond that horizon they discovered the elementary schools and followed that scientifically untouched anastomotic stream to its source in the kindergarten. K-12 has joined the language of science along with $K^{40}$, $C^{14}$, and $U^{235}$.

Finally scientists faced the inevitable and discovered the courses and curricula presented in their own colleges. Here they entered the chamber of horrors where unqualified secondary teachers are spawned. Every scientific discipline which is taught at the precollege level has a council, commission or committee seeking to improve courses and curricula for their undergraduate majors, for the preparation of teachers, and for general education. These groups are small and are for the most part crying in the wilderness of indifference and self-satisfaction with the overly professionalized status quo.

College courses in geology are being influenced by all of these events whether we realize it or not. However, it seems imperative that geology courses generally available to undergraduates should reflect the results of recent investigations of the earth. This applies especially to courses in geology which are traditionally available for general education and for the preparation of secondary teachers.

From 1961 through 1963 the American Geological Institute (AGI) sponsored a study of education in the geological sciences known as GEO-Study. This was a nationwide consideration of the intent and content of courses and curricula. A large number of geological scientists from industry, government, universities and colleges participated. Teams of scientists visited colleges and universities in all parts of the country for discussions with faculty, students and administrators. Conferences involving participants from all scientific and professional aspects of the geological sciences were held to analyze and summarize the findings. The results were published and widely distributed. One consequence of GEO-Study was the establishment of the Council on Education in the Geological Sciences (CEGS) which seeks, directly or indirectly, to implement the recommendations of GEO-Study.

Concerning the traditional courses in physical and historical geology the reports of GEO-Study recognized two major weaknesses. 1. These courses continue to emphasize the descriptive and taxonomic aspects of the subject matter and generally fail to emphasize concepts, principles and the challenge of unsolved problems. 2. There is a general failure to present stimulating and provocative exercises for the laboratory. The recommendations of GEO-Study gave highest priority to the need for drastic reorganization or replacement of these elementary courses. There is less than satisfactory evidence that this recommendation is being effectively implemented.

Failure to reorient the elementary geology courses continues in spite of important, even spectacular developments in earth science during the past decade. Nowhere is this more evident than in the consideration of earth materials, their nature and behavior. Analytical and experimental evidence has made it possible to approach an understanding of the silicate minerals which are the predominant constituents of the earth's crust. This can be much more fascinating and scientifically rewarding than memorizing the names, physical properties and chemical formulas of 50 or 150 assorted and unrelated minerals. The study of rocks in the traditional courses suffers from the same lack of emphasis on essentials. It is perhaps easier to present, and even to learn, a systematic classification of a dozen or two dozen igneous rocks than to explore to some depth the real nature and occurrence of the two really abundant types—granitic and basaltic. However, the latter can be fascinating and rewarding because it leads to understanding and to the discovery of a major unsolved problem in petrology.

The real difficulty with the traditional courses is the failure to provide a synthesis of recent developments. The failure to present minerals and rocks in a current and challenging fashion is matched or exceeded in the descriptive emphasis on processes and events. The failure to present some synthesis of the natural history of rocks (which might suggest four rather than three types) fails to provide a logical basis for a synthesis of events in the geologic history of the continents.

The "petrogenic cycle" consists of: 1. deposition of geosynclinal sediments, with or without volcanics; 2. orogeny and the development of plutonic (granitic) rocks and their metamorphic halos; and 3. the eruption of volcanics (typically basaltic). These events have occurred in elongated belts parallel to the margins of continental shields. Achieving and exploiting a synthesis of these events and processes requires the integration of data from many, seemingly unrelated, chapters scattered throughout the traditional texts in physical and historical geology.

Investigations of the earth during the past ten years provide a wide variety of data which must enter into the major syntheses to be developed in meaningful courses for general education and for teacher preparation.

The International Geophysical Year initiated research programs and intensified existing research programs in many of the broader aspects of earth science. High among its accomplishments was establishment of worldwide cooperation which is essential if meaningful results are to be obtained. Many geologists were piqued, and some remain so, because traditional aspects of geology were not included and because the word geology did not receive equal billing with geophysics. If geology is indeed the "science of the earth" it must be broad enough to encompass any and all scientific investigations of the planet and its environment in space. Another event of the decade of real but less direct significance to earth science is the program of the "year of the quiet sun" just being completed.

During the decade the scientific study of the atmosphere evolved from an emphasis on synoptic description of atmospheric phenomena and weather forecasting to an emphasis on the analysis and interpretation of atmospheric dynamics on a world-wide basis. The data from high altitude soundings (balloons and rockets) and especially from satellites are the bases for the new meteorology. Ground-based studies in micrometeorology are other significant developments. The organization of world-wide cooperation in these and other aspects of dynamic meteorology, and the reduction of data by computers are rapidly developing a basis for understanding the behavior of the earth's gaseous envelope.

World War II generated an intense need to better understand the oceans. Techniques developed during the war have been perfected and new techniques developed. World-wide cooperation has made a significant contribution to progress. Physical, chemical and biological investigations of the oceans, started long ago, have reached a degree of perfection which cannot be ignored in any introduction to the science of the earth. Investigations of the ocean floors are yielding data essential to an understanding of the dynamic behavior and history of the earth's crust. Studies of the deep sea sediments cannot be ignored in any serious attempt to understand the "great ice age" and other events of the past million years or so. During the past ten years the idea of boring a hole through the crust in an oceanic area has passed from a facetious jest through a period of bitter debate to a going project. Every secondary school student is aware of project Mohole and will be suspicious of any professed earth scientist who is unfamiliar with its purpose and scientific potential.

The most spectacular events of the decade are the many space probes, especially those to the moon, Venus and Mars. The most significant of these is the recent flyby of Mars. The pictures reveal a planetary surface more moonlike than earthlike. At first blush it appears that our closest planetary neighbor is not, and has not been, dynamic as is the case with the earth. The absence of evidence of erosion, orogeny and of a magnetic field suggests that Mars is a very unterrestrial terrestrial planet. The less definitive evidence provided by the flyby of Venus suggests that it too is an unearthly planet. The apparent contrasts between the earth and the other so-called terrestrial planets should strengthen the confidence of geological scientists that the earth is unique in most major respects. The answers to our problems must be sought here although the contrast will influence theoretical considerations.

Recent and ultimate success in resolving problems in the dynamics of the atmosphere, oceans and the solid earth depends on the reduction of data by computers. The computer provides the scientist with a phenomenal tool which, for the first time, permits him to reduce staggering volumes and varieties of data to manageable proportions. This could initiate a period of synthesis in science leading toward, if not to, unification.

Francis Bacon claimed that all knowledge was his province. Shortly thereafter Robert Hooke recognized that science must develop in two phases. First, the various parts of science were to be created and systematically investigated. During the second and later phase the parts would be brought together in a "complete system of solid philosophy." In the age of synthesis many of our proliferating scientific disciplines may emerge as a unified system of investigation in which the computer will test the intuition of the investigator. In that happy day most of our present flood of paper may prove to be mere pedantry.

Finally, there is one other event of the decade which is of peculiar significance to education in the geological sciences. This is the Earth Science Curriculum Project (ESCP) sponsored by AGI and supported by the National Science Foundation. This is an interdisciplinary program to produce a text and supporting materials for an earth science course to be given in the secondary schools. The text *Investigating the Earth,* a laboratory manual, and teacher's guide are being tested by more than 30,000 students this year. The course is laboratory centered and attempts to develop concepts and principles significant to an understanding of a dynamic earth. More important, the text and supporting materials seek to present a unified approach to the study of the earth. Events of the past decade are not neglected but are presented and exploited to the degree possible and appropriate for ninth graders. By careful design the course seeks to promote scientific understanding of earth materials and processes. Emphasis is placed on the importance of energy in the transformations and movements of earth materials. Based on such understanding, the history of the continents is developed in a systematic synthesis which leads to concepts of the origin of the earth and its place in the universe.

*Investigating the Earth* tries to avoid an emphasis on classification, techniques of identification and taxonomy. However, it is impossible to develop principles and concepts without facts, so one should not be surprised to find facts in the course. The presence or absence of facts is not a valid test of a text which purports to be 'concept oriented," it is what is done with the facts that counts. ESCP does avoid emphasis on the "hobby oriented" phases of earth science such as the classification and identification of minerals, rocks, and fossils. The writers have nothing against hobbies but they are writing a book for education in science and not for use in a recreation program. They believe that science, at its best, can and should be fun.

Secondary schools are notably lacking in teachers qualified to participate in a partnership with students in a scientific investigation of the earth. Most of the teachers using ESCP materials have little if any background in earth science. The most common background possessed by these teachers consists of the traditional courses in elementary geology. These are the very courses which GEO-Study insists should be replaced or drastically revised.

Geology is the only earth science discipline which commonly provides courses and curricula at the undergraduate level. In general, geology courses, including the elementary ones, and geological curricula have assumed an applied and professional emphasis. There is a proper place for this in higher education but in geology, where the baccalaureate degree is not adequate professional preparation, that place is in graduate colleges. As we enter the age of synthesis and unification of science it seems desirable that emphasis on specialization and professional development should be removed from undergraduate courses and curricula. Under the pressure of professional training geology teachers have increasingly found satisfaction and personal fulfillment in the creation of students in their own professional image. Courses and curricula have been designed to include at least an introduction to each of the plethora of emerging specialties in geology. Geology departments should ponder the words of E. G. Mesthene in a recent article "Learning to Live with Science" in the *Saturday Review* for 17 July 1965. "The evidence is becoming compelling that we are going to have to change these attitudes and comfortable habits. Careers are increasingly becoming shorter-lived than people. The challenge to education is indeed staggering." Courses and curricula must increasingly be designed to prepare students to appreciate the flood of emerging knowledge in all branches of science; to assist technology to discover what can be done with this knowledge; but more important to develop the wisdom to lead society in decisions respecting what *ought* to be done with both scientific knowledge and technology. For responsible members of society in 1980 or 2000, understanding of the sciences and technology will be an essential ingredient in their humane learning.

General education of the many and the education of earth science teachers require that someone offer unified undergraduate courses in earth science. These courses must be broad-based in the various specialized earth science disciplines and accompanied by laboratory studies. The laboratory work must contain challenging, open-ended, investigative exercises preferably without predetermined results. The exercises should not be organized to fit a two or three hour period or even some multiple of such.

Revision of the elementary geology courses to meet the needs of general education and of secondary teacher preparation is only a minor part of the emerging opportunity. The growth of earth science as a full year course in junior high schools is exceeding all expectations and predictions. The present annual requirement for new earth science teachers exceeds the number of baccalaureate graduates in all of the earth sciences combined. By 1975 the annual need for new teachers will be perhaps ten times the present production of graduates in the earth sciences. There must also be a substantial increase in the quality of the preservice education of secondary teachers. To meet these needs requires curriculum reform as well as course revision.

Baccalaureate graduates in the geological sciences are in increasing demand by industry. However, the visitation program and conferences conducted by GEO-Study revealed a consensus that the master's degree is minimum preparation for entry into the geological professions. This suggests that it may be desirable to decrease the professional orientation and specialization in undergraduate courses and curricula. Can revised courses and a curriculum including appropriate alternatives and flexibility meet the needs of both teacher and preprofessional preparation? This question can not be answered in the negative until educational statesmen in the geological sciences have exhausted their ingenuity and their determination to succeed. One potential advantage of imaginative revision of courses and curricula must be kept in mind. If well-prepared earth science teachers are bona fide graduates of geology departments it can be expected that they will encourage and prepare their better students to study geological sciences in college. Enlightened self-interest as well as educational, scientific and professional necessity should motivate geological scientists to be imaginative and original in meeting future educational needs. The alternative is that someone else will provide courses and curricula for the preservice preparation of earth science teachers, and geology will have successfully avoided another golden opportunity.